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A FLEXIBLE-OUTLET MIST SPRAYER

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A Flexible-Outlet Mist Sprayer

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The mist concentrate method of spraying fruit trees is being used by many growers in New York and adjacent states. Many of the machines available for this type of application are large and expensive. Much of the investigational work has been on machines with fixed or mechanically operated outlets. Comparatively little attention has been given to machines with hand-operated outlets.

The objective of this study has been the development of a sprayer that the grower with a small acreage can afford to buy and operate, one that will provide control of diseases and insects equal to that provided by conventional spraying methods. Such a sprayer should be light enough to be pulled through the orchard with a small tractor. It must be capable of developing sufficient air force for penetrating all parts of a tree with a reasonably uniform deposit of spray material. It should be relatively simple to operate and should not require much maintenance. The manipulation of the air outlet must not be too tiring for the operator. The point of discharge for air and spray material should be as low as is practicable. It has been the experience of the authors that trees are more satisfactorily sprayed by any method from a low position, which directs the spray upward through the leaf canopy, than by forcing it horizontally. The machine should be capable of applying either dilute or concentrated sprays.

In 1948 a machine of this type was developed cooperatively by the Departments of Agricultural Engineering, Plant Pathology, and Entomology, Cornell University.[1] Preliminary studies made of it in 1949 and 1950 indicated that it gave good disease control when it was used as a mist concentrate sprayer. A manually operated outlet of a hose type was used, and a rather large air outlet was found necessary to provide even distribution of spray throughout the tree.

Experimental Machine

The machine used in the experimental studies had a 100-gallon tank. A larger tank could be used on a commercial sprayer. The blower was a pressure-type radial flow fan. The engine was capable of developing 31 horsepower at 1800 r.p.m. A silent chain drive connected

AUTHORS' ACKNOWLEDGMENT. The authors wish to express their appreciation of the valuable suggestions made by Dr. R. M. Pratt in the design of the experimental sprayer described.

[1]The machine was assembled by the Hardie Mfg. Co., whose interest, suggestions, and cooperation are greatly appreciated.

the engine to the pump and blower. A speedometer was mounted on the front of the machine, where it could easily be seen by the tractor driver. (These features are shown in fig. 1.)

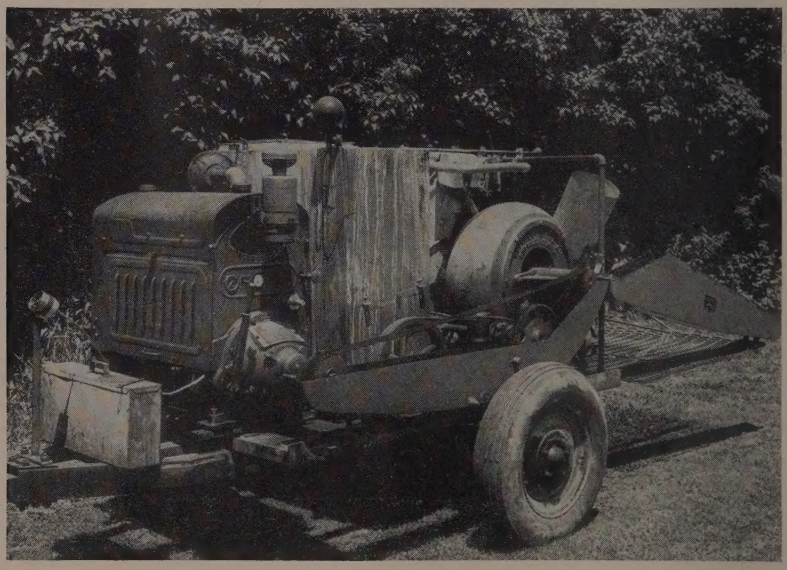
The pump was of a conventional high pressure plunger type, usually operated at 400 p.s.i. and was geared to deliver up to 18 gallons a minute when less concentrated mixtures were applied. Adequate atomization of spray mixtures has not been achieved so far without the use of relatively high pressures. There has been no difficulty with high pressure pump failures in applying concentrated spray mixtures.

How the machine operates

The air outlet was connected to the blower by a flexible tube, 4 feet long and 10 inches in diameter. The outlet nozzle was mounted low in a yoke and pivot device (fig. 2) and was equipped with a handle for easy operation from a standing position. This machine discharged air and spray material to one side only, but it could be built so that the direction of spray discharge could be easily changed from one side of the machine to the other.

It was determined that a 10-inch air outlet was better than smaller ones. With the 10-inch outlet, coverage on the trees looked uniform when the blower used was operated at 3000 r.p.m. With this arrangement 5000 cubic feet of air a minute were delivered at a velocity of 90 to 110 miles an hour.

Figure 1. **View of experimental sprayer, showing location of engine, tank, blower, drives, and speedometer.**



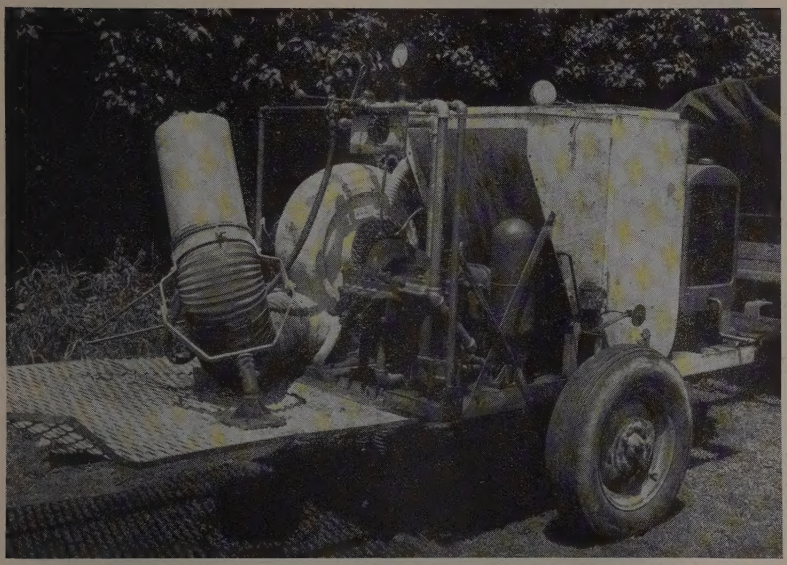


Figure 2. **View of experimental sprayer, showing yoke and pivot device for air-outlet mounting, and spray pump.**

At this air velocity spray collected on the inner surfaces of the air outlet and dripped from its outer edge to the ground. This difficulty was overcome by installing a ring 8 inches in diameter inside the outlet for the spray cone to strike against (fig. 3). With this device, air moving past the inner ring picked up any spray at the outer edge of the ring and carried it into the tree without loss.

A single spray nozzle of a cone type was used, with disc orifices ranging from 8/64- to 20/64-inch, depending on the delivery rate desired. The nozzle was mounted inside the air-discharge-tube, with the spray directed outward in the direction of air movement.

The machine required no more maintenance than the conventional high pressure sprayer. The suction line screen, tank, pump, and lines should be washed with water at the end of each day's operation.

Manipulation of air outlet

Two men were required to operate the sprayer: one to drive the tractor and the other to manipulate the outlet.

Spray material will be uniformly deposited throughout the tree if the outlet is manipulated so that the air stream describes a series of arcs and small loops, rotating the outlet in a direction opposite to that of travel along the row (fig. 4). The small loops are made when the air stream is directed towards the top of the tree. The long sweeping arcs are used to

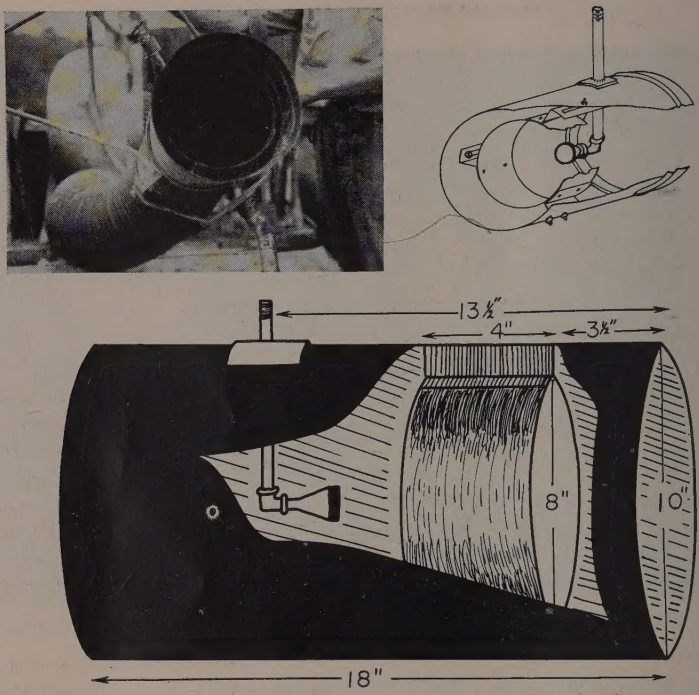


Figure 3. *(Caption on page 7.)*

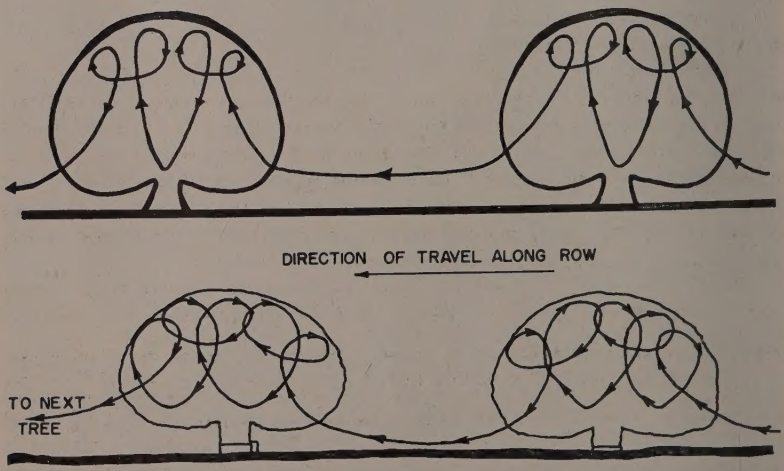


Figure 4. *(Caption on page 7.)*

spray the lower portion of the tree. The series of arcs and loops should be close enough so that the spray stream is directed towards all portions of the tree. To obtain uniform spray coverage it is necessary to direct more spray material towards the top of the tree than towards its lower portion, in a manner similar to the technique used in spraying with a spray gun. The speed with which the outlet is manipulated depends upon the tree size and rate of travel along the row.

It is less tiring to the operator to spray with this machine than it is to use a spray gun.

Disease Control Experiments

Sour cherry leaf-spot control

This experiment was performed in Wayne County in an orchard of Montmorency sour cherry trees. It was designed to test the performance of the flexible-outlet machine as a dilute sprayer and as a mist concentrate sprayer. Applications from this machine were compared with those from a conventional high-pressure sprayer. The spray from the latter was applied with a hand gun from the ground. The toxicant was a fixed copper.

The concentrations of toxicant applied with the mist sprayer were 1, 2, 4, and 8 times that recommended for conventional dilute spraying. The rate of delivery of the spray suspension was regulated to apply to each tree approximately the same amount of toxicant as applied with the gun. In addition a 6X, 1/8 delivery treatment was applied, for comparison with previous studies, many of which were made in this manner.

Table 1. **Sour cherry leaf-spot control, 1951**

Date	Percentage of leaves infected					
	Gun spray	1X Conc.	2X Conc.	4X Conc.	6X Conc.	8X Conc.
July 18	1.1	1.3	2.5	.23	2.3	2.0
Aug. 23	6.7	5.2	7.0	4.4	7.5	4.8
Sept. 26	10.5	10.8	10.7	6.9	10.3	9.4

Leaf-spot infection counts were made on three different dates. The percentage of infected leaves in each treatment was determined (table 1). The level of infection in all plots throughout the season was low, indicating that all treatments were effective. By the first week in August, severe leaf-spot defoliation was encountered in area orchards that had been poorly sprayed. Complete leaf-spot defoliation was observed in many orchards by September 1. No leaf-spot defoliation had occurred in the experimental plots when last examined on September 26.

The results in table 2 indicate that control in the tops of trees was as good with the mist sprayer as it was with the gun spray.

Figure 3. **Air outlet for flexible-outlet sprayer. *Top left:* photograph of air outlet used on experimental machine. *Top right:* perspective view of outlet, showing details of construction for making inner ring adjustable. *Bottom:* cut-away diagram, giving dimensions and relative position of parts.**

Figure 4. **Suggested pattern for movement of air stream of flexible-outlet mist sprayer. *Top:* suggested method of air-stream movement for spraying small trees. *Bottom:* suggested air-stream movement for spraying large trees.**

Table 2. **Sour cherry leaf-spot in tops of trees, 1951**

Date	Percentage of leaves infected		
	Gun spray	1X Conc.	6X Conc.
Sept. 20	14.1	12.7	13.1

The same treatments were applied to the same trees in 1952. The level of infection in the treated plots was so low that counts were not made.

Apple scab control

Apple scab is one of the serious fruit tree diseases. If a sprayer is to be useful to a fruit grower, it must be capable of making a deposit of spray material on the foliage and fruits of apple trees that is adequate for the control of scab.

In 1952 a scab control experiment was performed in Wayne County in a 25-year-old planting of McIntosh apple trees. The trees were in good vigor. They had a previous history of poor scab control. In 1951 the foliage and fruits in this orchard were essentially 100 per cent infected, and the crop was a total loss. These trees were 18 to 21 feet high, with a spread of 33 to 34 feet.

The objectives of this experiment were similar to those of the sour cherry experiment.

Wettable sulfur was used as the toxicant, and it was applied with the flexible-outlet mist sprayer at concentrations 1, 2, 4, and 8 times those recommended for conventional dilute spraying. The rates of delivery of the spray mixtures were regulated to apply approximately the same amount of toxicant to each tree as was applied with the spray gun.

Table 3. **Apple scab control and preharvest fruit drop, 1952**

	Mist spray				
	Gun spray	1X Conc.	2X Conc.	4X Conc.	8X Conc.
	Percentage of apple scab infection on foliage and fruits				
Foliage	25.8	22.1	17.3	24.4	19.8
Fruits	22.6	25.8	19.0	19.0	18.4
	Percentage of preharvest drop				
	18.6	6.8	13.0	6.7	9.6

The results in table 3 under apple scab infection indicate that scab control obtained with the mist sprayer was as good as that obtained with the spray gun. The results in table 3 under preharvest drop indicate that the spray-gun applications caused more preharvest fruit drop than did applications made with the mist sprayer.

Spray Deposit Studies

This experiment, conducted in Wayne County, was designed to test the efficiency of the flexible-outlet mist sprayer in making spray material deposits on large apple trees. A spray mixture of Crag Fungicide 341-SC

was applied at 4 times concentration with the flexible-outlet mist sprayer. This application was compared directly with that made with a spray gun spraying from the ground. The trees sprayed were large Baldwins that had not been pruned during the previous year and were relatively dense. They were 24 to 26 feet high, with a spread of 30 to 34 feet.

Leaf-disc samples from the lower parts of the trees were taken at a convenient height from the ground. A separate sample was taken from each quadrant of each count tree. Two duplicate samples were taken from the top-center of each count tree, each sample including leaf discs from all parts of the top of the tree. The height of sampling was as high as the trees could be climbed. The amount of toxicant deposited was determined by William J. Tucker, of the G.L.F. Quality Control Laboratory in Ithaca, and Robert Shoemaker, of the Department of Plant Pathology, Cornell University.

The results in table 4 give evidence that satisfactory distribution of fungicide deposits can be obtained throughout large apple trees with the flexible-outlet mist sprayer.

Table 4. **Spray deposit expressed as milligrams deposited per 600 square centimeters of leaf surface, for each pound of toxicant (341-SC) applied**

Sampling location	Gun spray (dilute)	Flexible-outlet sprayer (4X conc. ¼ delivery)
Top of tree	13.41	15.20
Bottom-near*	9.90	10.77
Bottom-far†	11.84	11.10
Average-bottom	10.87	10.94

*Samples from the quadrants of the trees that were nearest to the line of travel of the machines.

†Samples from the quadrants of the trees that were farthest from the line of travel of the machines.

Insect Control Experiments

No insect control results are available on the equipment described in this bulletin. Insect control data were obtained with this machine in 1948, when a 7-inch outlet and a different spray nozzle were used and the blower was operated at a lower rate of speed.

A full season's insecticide program of 4 cover sprays was applied for the control of red-banded leaf roller and codling moth in two experiments in Wayne County, New York. The mist sprayer was compared directly with the conventional gun spray. The gun spraying was done from the rear platform of the sprayer. DDT, sulfur, and Veg Oil were used in all applications.

The first experiment was in a poorly pruned block of 20-year-old McIntosh apple trees, which were about 16 feet in height. The concentrations of DDT applied were 4 and 8 times the concentration recommended for conventional dilute spraying. The dosage rate of the spray for each tree was adjusted to apply the same amount of toxicant in the 8X treatment as in the gun spray. The 4X treatment was applied at approximately the same gallonage of spray as the 8X treatment. Thus, the total amount of

toxicant applied to each tree was about one-half that applied with the 8X and gun spray treatments.

The percentage of injury from codling moth and red-banded leaf roller was determined at harvest (table 5). The codling moth infestation in this orchard was low, and no statistically significant differences between the treatments were demonstrated. Control obtained with the mist sprayer, however, was equal to that obtained with the gun spray.

Table 5. **Insect control, 1948**
(Codling moth and red-banded leaf-roller)

Treatment	Per cent injury	
	Codling moth	Red-banded leaf roller
Gun spray	1.8	28.8
Mist spray		
4X	2.8	46.1
8X	1.7	26.5

The red-banded leaf roller infestation was moderately heavy. DDT is not generally considered a suitable toxicant for control of this pest, but control obtained with the 8X treatment was slightly better than that obtained with the gun spray. Both the 8X and gun spray treatments gave significantly better control than did the 4X treatment, which was applied at one-half the dosage rate of the other two.

In the second experiment, 22-year-old Wealthy apple trees were sprayed. These trees were poorly pruned and were about 14 feet high. The mist spray was applied at 8 times the concentration recommended for conventional dilute spraying. The rate of spray delivery was adjusted to apply the same amount of toxicant to each tree as was applied with the gun. Two formulations of DDT wettable powder were applied with the mist sprayer, and compared with one formulation applied with the gun.

Heavy infestations of both codling moth and red-banded leaf roller were present in this orchard. In general, the same control was obtained with both methods of spraying (table 6).

Changes have been made in the experimental mist sprayer since these experiments were done. These changes, based on deposit data and disease control, have resulted in a more uniform deposit of material and better coverage of large trees without a decrease in the amount of material deposited. Consequently, with the machine as now set up, control at least as good as that obtained in 1948 is to be expected on all trees.

Table 6. **Insect control, 1948**
(Codling moth and red-banded leaf-roller)

Treatment	Per cent injury	
	Codling moth	Red-banded leaf roller
Gun spray	9.0	22.8
Mist spray 8X		
DDT "A"*	11.5	17.3
DDT "B"*	11.0	21.7
Untreated check	44.9	44.4

*These were essentially the same except for the diluents for the DDT.

How to Use Machine

It is suggested that growers who have not had experience in applying concentrated spray mixtures begin by using mixtures concentrated not more than four times the concentration used for dilute spraying, because uniform coverage of foliage is more easily obtained at this concentration than at higher ones. With experience, a grower may use more concentrated mixtures with the expectation of obtaining good disease control.

Foliage and fruits must be adequately covered with spray material to obtain satisfactory control of diseases and insects. The grower must determine the concentration, delivery rate of spray material, and driving speed that will provide adequate spray coverage for his trees. This may be done by spraying several trees, then climbing them to observe the amount and distribution of the spray material deposited.

A method for determining the delivery rate that may be used is as follows:

1. Determine the number of gallons of dilute spray required to spray a representative tree in the orchard.

2. If four times concentration is to be used, divide the number of gallons determined in step 1 by four. The figure thus obtained is the number of gallons of concentrated spray mixture required to apply the same amount of toxicant to a tree as would be applied with the spray gun.

3. Select a suitable driving speed. For the flexible-outlet mist sprayer this should be not more than 1½ miles an hour, and for larger trees it may well be less than 1 mile an hour. Better spray coverage of trees is obtained at low driving speeds.

4. Determine the tree spacing. From the tree spacing and the driving speed, the number of trees passed per minute can be determined from table 7.

Table 7. **Number of trees passed per minute at various driving speeds, with different tree spacings**

Speed in mph	Tree spacing in feet								
	16	18	20	22	25	30	35	40	45
1	5.5	4.9	4.4	4.0	3.5	2.9	2.5	2.2	2.0
1½	8.3	7.3	6.6	6.0	5.3	4.4	3.8	3.3	2.9
2	11.0	9.8	8.8	8.0	7.0	5.9	5.0	4.4	3.9

5. Multiply the number of gallons to be delivered per tree (step 2) by the number of trees passed per minute (step 4). Divide this figure by 2 (because only one-half of the tree is sprayed as it is passed) to obtain the number of gallons per minute the machine should deliver. This calculation will determine the spray nozzle disc size for providing the proper delivery rate of spray per minute.

Availability of Machine

This machine is not on the market at present. It can be built by growers who have machine shops or in small metal-working shops. The parts such as the tank, blower, pump, engine, and drives can be purchased separately and assembled without much difficulty.

Construction Details

The essential parts of the sprayer are:

Tank (200-gal. capacity) with mechanical agitator and suitable openings for filling, pump suction line, and drain connections

Suction line screen

Plunger pump (23 to 25 g.p.m. at 400 p.s.i. capacity)

Blower (5000 c.f.m. at 6 to 7 inches water static pressure)

Engine 30+ H.P. (liquid-cooled preferred)

Flexible tubing (4 feet long, 10 inches in diameter)

Air nozzle with yoke and pivot support

Suitable pipe fittings, valves, and high pressure hose; also an ordinary nozzle with an assortment of discs

Bearings, countershafts, sprockets, and chain or V-belts and pulleys.

The weight of the machine with a full tank is about 3400 pounds. The frame, axle, and wheels for the trailer should be selected accordingly.

Blower

The blower used must supply 5000 cubic feet of air a minute at an outlet velocity of 90 to 110 miles an hour. It should be operated at speeds recommended by the manufacturer. V-belt or chain and sprocket drives may be used, chosen according to manufacturer's recommendations. An enclosure should be provided to prevent spray material from getting on the belts and pulleys or chain and sprockets.

Pump

For general use with concentrated and dilute mixtures a high pressure pump with a capacity of 23 to 25 gallons a minute is suggested. Plunger pumps are best suited to this service, for they wear less rapidly than other types, particularly with high concentrations of spray materials. Other types do not stand up as well under high pressures; they are not as efficient and do not give the same length of service. Provisions for repairs and service are particularly important. A chain drive is suggested for the pump.

Engine size

A 25 H.P. air-cooled engine was tried on the experimental machine; it seemed to lack the necessary power to give satisfactory drive to the spray materials. The 31 H.P. liquid-cooled engine did much better. Fan size and efficiency as well as pump capacity and pressure will be the governing factors in selecting an engine. The rated engine H.P. should be 33 per cent greater than the combined requirements of the blower, pump, and agitator.

Construction of air outlet

The dimensions of the outlet are given in figure 3. It should be made of 20-gauge or heavier sheet metal.

The exact positioning of the inner ring will depend upon the type of spray nozzle used. Provisions are made in the design of the outlet to permit adjustment of the inner ring.

A flexible tube 4 feet long and 10 inches in diameter is used to connect the outlet to the blower. This hose is made in different weights with or without spiral reinforcing wire, which is considered advisable though not absolutely necessary. Medium-weight tubing with wire reinforcing was found to be quite durable.

Construction of air outlet mounting

Diagrams for the construction of the yoke and pivot device for mounting the air outlet are given in figure 5.

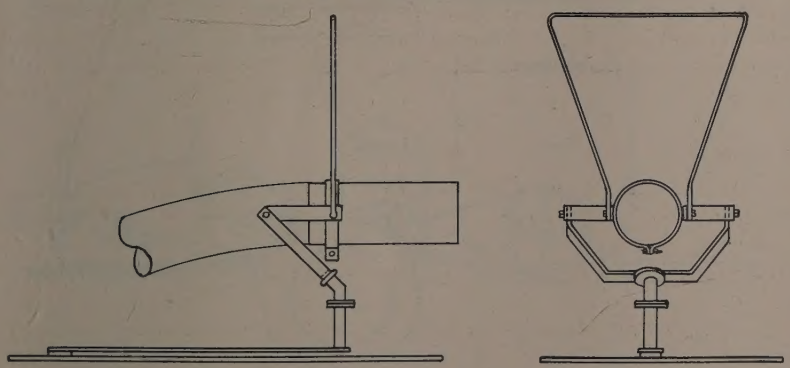
Size of sprockets and pulleys

The size of the sprockets and pulleys will be determined by the engine, pump, and blower speeds. Manufacturers' rating tables should be consulted. (Manufacturers are usually glad to help with special designs.)

General suggestions

The spray discharge should be controlled by a quick-acting valve. A valve for draining the tank should be conveniently located, to facilitate cleaning of the tank. A suction line screen similar to that used on the conventional high pressure sprayer provides adequate screening of the spray mixtures. A pressure gauge should be installed in a convenient loca-

Figure 5. **Side and front face views of mounting for air outlet.**



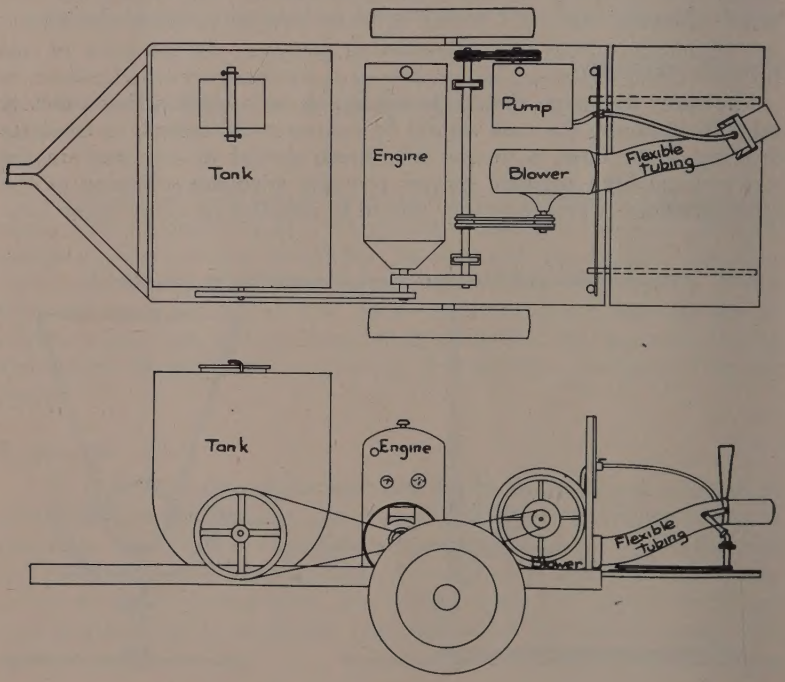
tion, so that the pump operation can be checked. A speedometer is an important item on sprayers or tractors that are to be used to apply concentrate sprays. For a list of manufacturers of the various components, write the Department of Agricultural Engineering, Cornell University.

Suggestions for assembly of sprayer

The diagrams in figure 6 suggest an arrangement for the various parts of the sprayer. Most farm implement dealers and repair men now have power saws, drill presses, and electric and gas welding equipment. They make trailers for general purpose work and for special jobs such as the assembly of this sprayer. A good mechanic can make a suitable layout of the equipment, weld a solid frame on a truck axle, and assemble the parts in their proper location to allow satisfactory drives from the engine to the agitator, pump, and blower.

The trailer frame should be made very rigid to prevent warping, with resultant slippage of the drives, and undue stress on the machine. Depth adds strength and stiffness to a frame. Cross and box sections found in auto frame construction make for maximum rigidity with low weight.

Figure 6. **Suggested arrangement of components for assembly of sprayer.**



Discussion

A small orchard sprayer suitable for use as a mist concentrate sprayer or as a dilute sprayer has been developed. Disease and insect control results have been favorable. Deposit studies indicate that large trees can be sprayed effectively. The sprayer is light enough for use with small tractors.

For satisfactory results, a machine of this type must supply an air discharge of at least 5000 cubic feet a minute at a velocity of 90 to 110 miles an hour. A high pressure pump is used to provide adequate atomization of the spray mixture. A 200-gallon tank should be sufficiently large for commercial operation (200 gallons of a 4X mixture are equivalent to 800 gallons of a dilute spray mixture). Occasions may arise when it will be necessary to dump a tankful of spray mixture, and it would prove very expensive to discard many gallons of a concentrated mixture.

The operation of the machine is similar to that used in making spray gun applications. For this reason the operator can quickly learn to use the machine efficiently. The manipulation of the air outlet is not unduly tiring for the operator — it is much less tiring than using a spray gun.

The machine is simple to operate and maintain. It should be relatively inexpensive because of its size and simple construction. Two men are required to operate it, but there are few fruit farms that do not have two men available.

This machine was developed primarily for the fruit grower who does not have enough acreage in orchard to support larger one-man machines. It can be of use to growers with larger acreages for special jobs such as preharvest applications on peaches, for it avoids the damage done to the crop by larger machines. It may also be used to advantage in plantings of young trees where larger air blast machines do not make efficient use of spray materials.

The design of the machine is not complicated. It could be assembled in the farm shop or in small metal-working shops.